

Section 7020
(October 2002)

7020	Fire Behavior and Maps
7020.1	Fuel, Weather and Topography
7020.2	Rate of Spread
7020.3	Maps (see Field Ops Guide)
7020.4	National Fire Danger Rating System (NFDRS)
7020.4.1	NFDRS Outputs
7020.4.2	Fire Danger Classes
7020.4.3	Fire Danger Pocket Cards
Exhibit	USGS 7-1/2 Minute Quad Slope Overlay
Exhibit	USGS 7-1/2 Minute Quad Acreage Overlay
Exhibit	USGS 15 Minute Quad Slope Overlay
Exhibit	USGS 15 Minute Quad Acreage Overlay

Firefighter safety and your strategy and tactics at a wildland fire must be based on fact (what the fire has already done) and prediction (what the fire is expected to do). Your prediction of what the fire will do is based on knowledge of the three components of the wildland fire triangle: [fuel](#), [weather](#), and [topography](#).



The combined effects of fuel, weather and topography create “fire behavior”, made visible by [fire behavior indicators](#).

FUEL FACTORS

Fuel Characteristics

- **Fuel size class definitions.**
 - 1 hour fuels = less than 1/4" diameter
 - 10 hour fuels = 1/4" to 1" diameter
 - 100 hour fuels = 1" to 3" diameter
 - 1000 hour fuels = 3" to 8" diameter
- Continuous “fine fuels” (1 hour fuels) provide the greatest potential for critical [rates of spread](#).

Fuel Moisture:

- Fuel moisture content determines if fuels are ready to burn
 - Live fuels get their moisture from the ground
 - Relative Humidity (RH) determines the dryness of a dead fuel

Rule-of-thumb

Critical-level fine dead fuel moisture occurs when the RH reaches 25% or below.

Fuel Temperature:

- The higher the fuel temperature the easier the fuel is to burn
- South and Southwest aspects have highest amount of direct solar radiation and generally have the highest average fuel temperature.

Rule-of-thumb

If the fuels in an area about to change from being in the shade to being in sunlight, expect an increase in fire behavior!

WEATHER FACTORS

Wind:

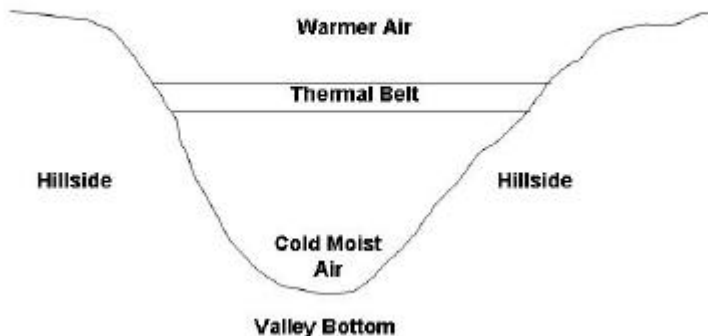
- Wind is the primary factor that influences fire spread. This includes both the rate and direction of spread.
- Winds changes can be diurnal (night or day), or caused by the movement of fronts or the result of gradients between pressure systems.
- Fire convection columns will produce wind of varying velocity and direction causing erratic, unpredictable fire behavior.
- Approaching cold front
 - Winds will shift and increase in speed as a cold front approaches.
 - Winds will typically change from the southwest to the northwest and become stronger and more erratic.
- Foehn winds are the result of high-pressure systems and mountainous terrain.
 - The conditions that cause these winds are predictable by weather forecasters.
 - Foehn winds occur in several areas of the country.
- Battling winds or sudden calm
 - When a gravity or Foehn wind interacts with a local wind significant wind reversals are likely.
 - Definite indicators are:
 - 1) Winds battling back and forth causing a waving smoke column and a sudden calm.
 - 2) A decreasing Foehn wind may allow a local wind to regain influence. This can be as dangerous as the Foehn wind that overpowers a local wind.
 - 3) A wind reversal from a decreasing Foehn wind has been a factor in several fatality fires.
- Strong down slope winds can overcome the influence of slope.

Atmospheric Stability:

- When sizing up atmospheric stability, we are most concerned with an unstable air mass that provides the potential for vertical fire development and rapid growth.
- Unstable Air Mass Indicators
 - Good visibility
 - Gusty winds
 - Dust devils
 - Cumulus clouds
 - Castellatus clouds
 - Smoke rising straight up
 - With these indicators a fire will have the potential to develop in the vertical direction and grow rapidly.
- Stable Air Mass Indicators
 - Poor visibility (fog, smoke, haze, etc.)
 - Steady winds (not gusty)
 - Stratus clouds
 - No defined smoke column (not rising straight up)
 - With these indicators the atmosphere is resisting vertical motion. The fire usually will not be intense.
- Inversions
 - Cool air off slopes pools in basins and valleys
 - They are most likely to occur, late afternoon early evening
 - The cool air is usually moist
 - The fuel moisture is typically higher
- Thermal belt

The thermal belt is a zone of warm nighttime temperatures and lower nighttime RH's. The behavior of a fire that is burning in a thermal belt will reflect these conditions.

 - A thermal belt forms at the top 2/3 of a night inversion



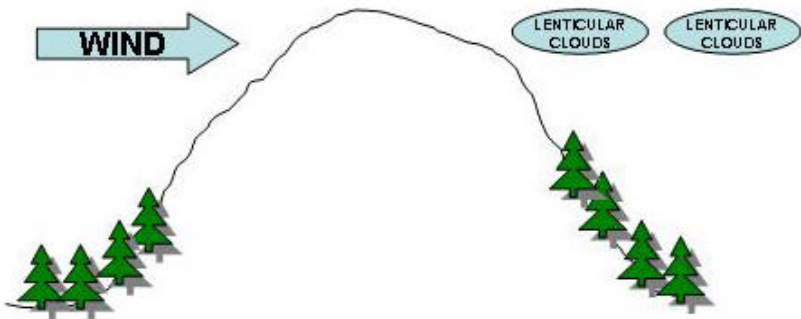
- Inversion lifting or breaking

When an inversion begins to lift or break, the air mass is in transition from stable to unstable. The behavior of a fire burning beneath an inversion may change abruptly when the inversion is destroyed.

- An inversion lifts or breaks as a result of:
 - Winds that mix and scour the stable air
 - The heating and lifting effect of solar radiation

Inversions tend to set a pattern for the time of day that they lift or break; be aware of this pattern, as fire behavior will change accordingly.

- Lenticular clouds indicate high winds aloft with potential to drop to the surface and produce strong down slope winds.



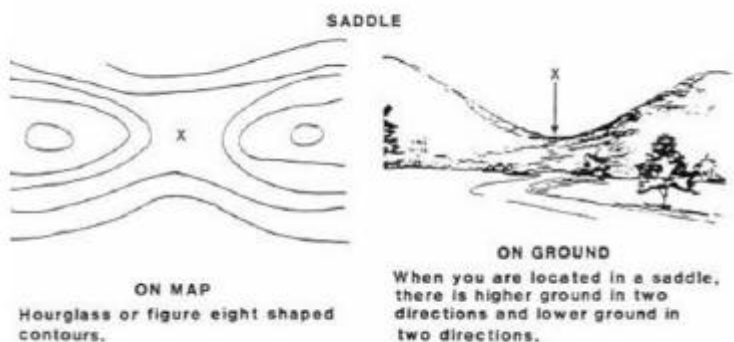
- High fast moving clouds indicate potential wind shifts particularly if the clouds are moving in a direction different from the surface wind.
- Cumulonimbus development
 - Thunderstorms present the potential for strong erratic winds.
 - If you see cumulus clouds building into a thunderstorm anticipate possible downdraft winds.
 - Thunder and lightning are associated with these storms.

- Virga may be observed. Virga is the rain that does not reach the ground. This is a good indication that downdrafts have begun.
- Downdrafts can reach speeds of 35+ mph and can travel in any direction when they hit the ground.

TOPOGRAPHY FACTORS

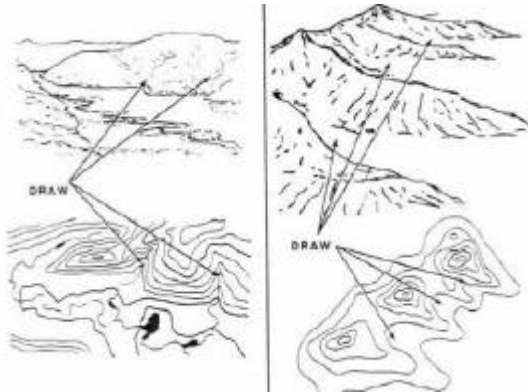
Terrain:

- Steep slopes
 - Steep slopes provide potential for rapid upslope rates of spread
 - Downhill spotting problems are a concern on steep slopes due to rolling of burning material.
 - Steep terrain is one of the common denominators of fatality fires.
- Saddles



These features will typically have chimneys on both sides of the saddle.

- Saddles provide potential for rapid rates of spread.
- Fires are pushed through saddles faster during upslope runs.
- Fire lines constructed on ridges often drop into saddles.



- Canyons and draws
 - Narrow canyons provide potential for rapid rates of spread from two sources:
 - Radiant or convective spotting can occur across narrow canyons due to the short distances involved. This can cause multiple spot fires leaving you in the middle.
 - A slope reversal can occur when a fire backing downhill reaches the opposite slope and begins a rapid upslope run another caution when working in narrow canyons.
- Intersecting drainages
 - This is where 2 or more drainages or draws come together.
 - The wind eddies that occur in these intersections or forks can cause very erratic fire behavior.
- Box canyons and chutes provide potential for very rapid upslope rates of spread by combining steep terrain with updrafts of air. This is called the "Chimney Effect".

Fire Behavior Indicators:

- Leaning column
 - Fast/critical rates of spread
 - Short-range spotting
 - Typical of wind driven fires

- Sheared column
A column of smoke that rises up and abruptly changes direction with a 90-degree bend.
 - This means winds aloft
 - May cause long-range spotting
 - The winds may have the potential to surface
 - Avoid working under a sheared column
- Well developed column
 - Intense burning
 - Unpredictable fire spread in any direction
 - A Plume Dominated fire occurs when the power of the fire becomes stronger than the power of the local winds. The danger of a plume-dominated fire is the potential for down bursts that are similar to, but stronger than, downdrafts from a thunderstorm. If a fire has a well-developed column and you feel a light rain on the fire line or experience a sudden calm, you can expect down bursts.
- Changing column
 - A column that is changing to a darker color, beginning to rotate faster, or splits can indicate fire behavior is increasing.
- Trees torching
 - Torching trees are an indicator that a fire is starting to transition from a surface fire to a crown fire.
- Smoldering fire picking-up
 - Observe fire activity by monitoring flame length and rate of spread.
- Fire whirls
 - Fire whirls are another indicator that a fire has the potential to move from a surface fire to a crown fire.
 - Fire whirls also provide a mechanism for spotting to occur.
- Frequent spot fires
 - Spot fires increase fire spread and complexity.
 - Beware when you are getting spot fires faster than you can get people to work on them.
- Rate of Spread increasing
 - More efficient heat transfer (as with wind and/or slope aiding) causes new fuel to heat up more rapidly.

ROS is defined as the rate at which the flame front advances through the fuel.

- Measurement Terms of ROS
 - Low (slow) - very little spread, spread of no consequence
 - Moderate - spread less than 1 MPH
 - Dangerous - spread is 1-3 MPH
 - Critical - over 3 MPH
- The ROS influences the choice and timing of control actions.
- The ROS influences safety.
 - How soon will the fire threaten personnel or equipment?
 - When might potential escape routes be cut off?

FUEL MOISTURE CONTENT- RATE OF SPREAD FACTOR

25%	1
20%	2
15%	3
10%	7
5%	20
3%	32

Instructions: Using the first line of 25% fuel moisture, any decrease in fuel moisture will increase the ROS by a factor shown on the right side. For example, if you had a 15% fine dead fuel moisture and the fuel moisture decreased to 10% then you can expect the ROS to go seven (7) times faster. If you start with 25% fine dead fuel moisture and the fuel moisture drops to 10% then you can expect the fire's ROS to increase 13 times faster (accumulative).

Note: that as fuel moisture decreases, rate of spread can be expected to increase at a much more rapid rate.

RULES-OF-THUMB FOR RATE OF SPREAD CHANGES

- (a) As the fire history doubles, the amount of fire line to be constructed doubles.
- (b) Disregard fuel moisture changes in an initial attack situation. It won't change critically over a short period of time.
- (c) As the wind speed doubles, rate of spread doubles.
- (d) Fuel Type:
 - 1) From brush to grass, the rate of spread will approximately double.
 - 2) From timber mixed with brush to grass, rate of spread will approximately triple.

- 3) From timber and second-growth to grass, rate of spread will approximately quadruple.
 - 4) From timber and second-growth to brush, the rate of spread will approximately double.
 - 5) Slope; the rate of spread will approximately double for each 20% increase in slope.
- Another method to estimate the potential ROS is to obtain the RH, wind and slope measurements and use the matrix below.

LEVEL TERRAIN – SLOPES LESS THAN 20%

Wind Velocity	Relative Humidity			
	Above 40%	26 - 40%	15 – 25%	Below 15%
0 – 12 mph	Low	Moderate	Moderate	Dangerous
13 – 24 mph	Moderate	Dangerous	Dangerous	Critical
Above 24 mph	Dangerous	Dangerous	Critical	Critical

SLOPES GREATER THAN 20%

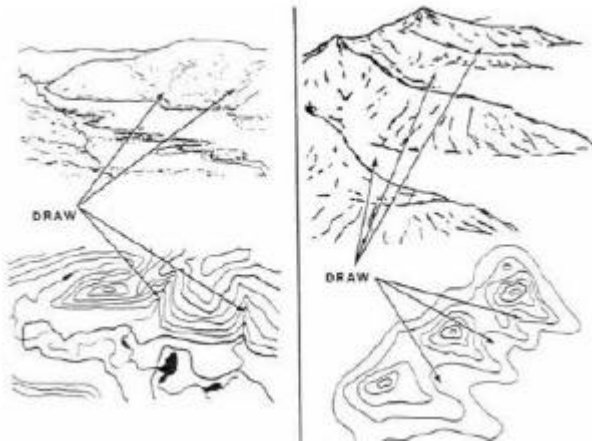
Wind Velocity	Relative Humidity			
	Above 40%	26 - 40%	15 – 25%	Below 15%
0 – 12 mph	Moderate	Moderate	Dangerous	Critical
13 – 24 mph	Dangerous	Dangerous	Critical	Critical
Above 24 mph	Critical	Critical	Critical	Critical

MAPS (See Field Ops Guide)
(October 2002)

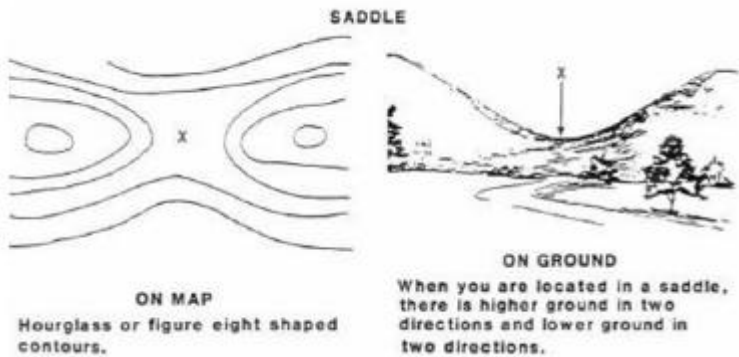
7020.3

Rules about contour lines:

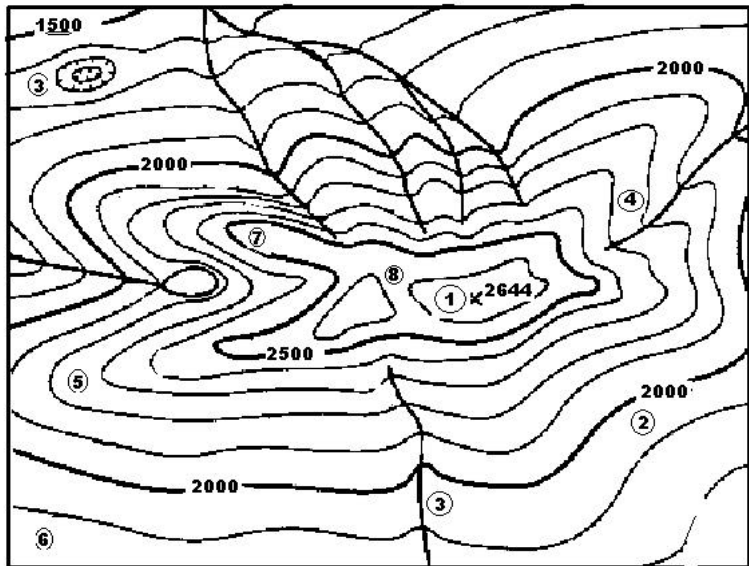
1. Usually have smooth curves. Exceptions are large outcrops of rocks, cliffs, and fractured areas of the earth's surface.
2. "V" shaped in streambeds and narrow valleys. The point of the "V" always points uphill or upstream. Also know as draws, chimneys or chutes.
3. "U" shaped on ridges with the "U" bottom pointing down the ridge.



4. The area between two closed contours is called a saddle.
"M" or "W" shaped just upstream from stream junctions. They tend to parallel streams and each other, each approximately the shape of the one above it and the one below it.
5. Closely spaced contours indicate steep terrain
6. Equally spaced contours indicate a uniform slope



How to read contour lines:



- | | |
|------------------------------------|---|
| 1 - MOUNTAIN TOP | 2 - INDEX CONTOUR AND CONTOUR LINE |
| 3 - DEPRESSION | 4 - DRAINAGE |
| 5 - RIDGE LINE | 6 - WIDELY SPACED CONTOURS |
| 7 - TIGHTLY SPACED CONTOURS | 8 - SADDLE |

- Index Contour - To make the contours easier to read, every fifth one is printed darker and has the elevation marked every so often in the line.
- Contour interval - The distance in elevation (rise or fall) between two adjacent contour lines.

How to calculate slope:

1. Check the scale and measure the distance between the two points you wish to calculate for. Distance = "RUN".

For example:

If the distance between two points is 2" using the rule-of-thumb shown below the distance is 4,000 feet.

2. Next check the elevation rise or fall. One way to do so is to count the number of contour lines between the two points and multiply the number intervals by the contour interval. Now you have the "RISE". If the contour interval is not listed in the legend then find two adjacent index contours with the slopes printed and divide that number by 5. This will give you the contour interval.

For example: If there are 25 contour lines and the interval is 20 feet then the elevation change is 500 feet.

Using the calculation of RISE divided by RUN times 100 and using the Example above: 500 divided by 4,000 times 100 or 12.5% slope.

Another method used to calculate slope is to use the USGS 7-½ minute Quad Slope Overlay.

See [USGS 7-1/2 Minute Quad Slope Overlay](#) and [USGS 7-1/2 Minute Quad Acreage Overlay](#)

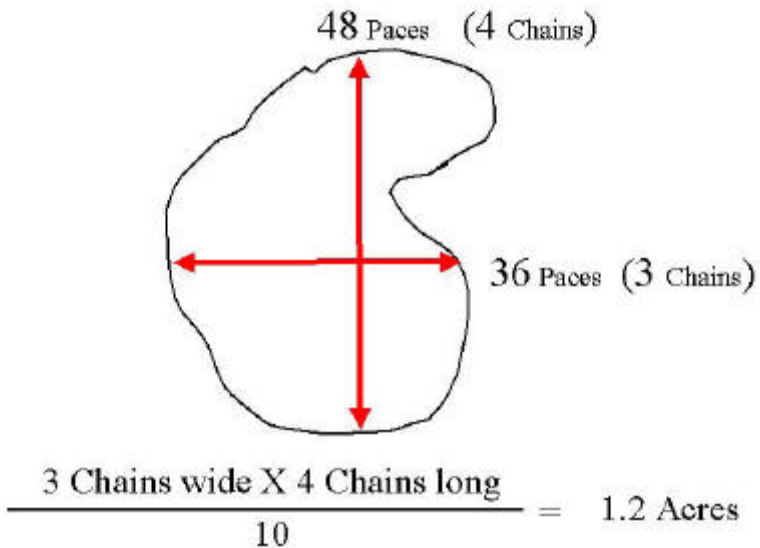
1. Using the overlay place the circle over the area you wish to estimate the slope for
2. Count the number of contour lines with the circle
3. Identify the contour interval
4. Using the matrix find the estimated slope for the two values you gathered. If the Contour interval is 10 feet, take the 20-foot contour interval and divide by 2.

Estimating acreage

To estimate acreage for a report on conditions or fire report:

1. Using a USGS 7 ½ minute map, draw the current or final fire perimeter. Count the number of sections the fire is completely within. Each **section** on the map is 640 acres. To estimate how much area has burned, divide the sections into quarters. Using this method, a section can be divided down to a square representing 2.5 acres. Overlaying a burned area onto map with section lines and then dividing that section into smaller sections (quarters) will offer a method to calculate the estimated size of the burned area.

Example: If you have a situation where 3 sections were consumed approximately 1/2 by fire, then for each of those sections the fire **burned 320 acres for a total burned area of 960 acres (320 X 3 = 960).**



See [USGS 15 Minute Quad Slope Overlay](#) and [USGS 15 Minute Quad Acreage Overlay](#)

Units of Measure - The more you know about figuring areas the easier it is to read maps. Some common units and formulas you should know are;

Linear Units

Foot	= 12 Inches	
Yard	= 3 feet	= 36 inches
Chain	= 66 feet	= 22 yards
Mile	= 5,280 feet	= 80 chains

Area Units

Acre	= 43,560 sq. ft.	= 208' x 208'	= 10 sq. chains
Sq mile	= 640 acres		
Section	= 1 sq. mi.		

Formulas

Rectangle/square $Area = Length \times Width$
Circle Area = $3.14 \times Radius^{(Squared)}$

For a 7 ½ minute quad:

- For every 2.64" on the map it is equal to 1 mile on the ground
- For every 1" on the map it is equal to 2,000' on the ground
- For every 1/10 of an inch on the map, it is equal to 200' on the ground
- 3 chains per 1/10 of an inch
- 30 chains per inch

Map Scale

The map scale indicates the ratio or proportion of the horizontal distance on the map to the corresponding horizontal distance on the ground. For example for a 7 ½ minute USGS quad every 2.64 inches on a map that would equal 1 mile on the ground.

Map Colors

In order to make the identification of features on a map easier to interpret and to provide more natural appearance and contrast, map symbols are usually printed in colors with each color representing a class of features. The colors are as follows:

- Black - Most cultural or human-made features, boundaries.
- Blue - Water features such as lakes, rivers, or swamps.
- Green - Vegetation such as woods, orchards, or vineyards.
- Brown - All relief features, contours, cuts and fills (Topographic maps).

- Red - Main roads, built-up areas, boundaries, special features.
- Other colors may be used for special purposes. Their key will be found in the margin/legend of the map.

Rectangular Land Division

Section–Township – Range

This land division system is based on an *Initial Point* (also called a Reference Point). There are 31 of these Initial Points in the contiguous U.S. and 3 in California. Initial Points are located at the intersection of two reference lines.



The three reference points in California are:

Through each of the Initial Points there is a North-South line called a Principal Meridian and an East-West line called a Baseline

The Base Line is an imaginary line running East-West through the Initial Point.

The Principal Meridian is an imaginary line running North-South through the Initial Point.

Township lines: Township lines are east-west lines that are 6 miles apart and run parallel to the base line. The rows formed by these lines are numbered consecutively, beginning with one in the row closest to the base line. An N or an S to describe whether it is north or south of the base line.

Range lines: Range lines are north/south lines that are 6 miles apart and run parallel to the principal meridian. The columns formed by these lines are numbered consecutively, beginning with one in the row closest to the principal meridian. The number is followed by an **E** or a **W** to describe whether it is east or west of the principal meridian.

Townships: The intersection of Township and Range Lines forms a grid of squares, containing 36 square miles each (6 miles x 6 miles). These squares are called Townships.

Townships are referenced in the fashion as an Alpha-Numeric Grid with the township reference given first, the range reference given second, and the appropriate initial point given last.

Sections

Townships define a land area of 36 square miles. To define smaller areas townships are divided into 1-mile squares called Sections. Sections are numbered in an alternating horizontal sequence beginning with 1 in the northeast corner and ending with 36 in the southeast corner. Each section is 640 acres.

2 N	6	5	4	3	2	1
	7	8	9	10	11	12
	18	17	16	15	14	13
	19	20	21	22	23	24
	30	29	28	27	28	25
	31	32	33	34	35	36
3 E						

Section Halves and Quarters

Sections define a land area of one square mile. To define smaller areas sections may be broken down into various combinations of halves and/or quarters. They are described in terms of cardinal directions.

W ½ Sec 21	E ½ Sec 21
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Section Halves are rectangular and are described in terms of N, S, E, or W. Each half equals approximately 320 acres.

A	B
C	D

Section Quarters are square and are described in terms of NW, NE, SW, or SE. Each quarter equals approximately 160 acres.

For example:

A = NW $\frac{1}{4}$, Sec. 22 B = NE $\frac{1}{4}$, Sec. 22

C = SW $\frac{1}{4}$, Sec. 22 D = SE $\frac{1}{4}$, Sec. 22

	A	
		B

Section quarters can be further divided into halves and quarters to estimate acreage.

A = W $\frac{1}{2}$ of the NE $\frac{1}{4}$, Sec. 6

B = NE $\frac{1}{4}$ of the SE $\frac{1}{4}$, Sec. 6

Map Symbols

In order to make maps easier to read, symbols have been developed to represent actual locations or items on the ground. These symbols will be found in the map legend if one is provided. The standard ICS symbols shown below can also be found in the "Fireline Handbook, Page A-31"

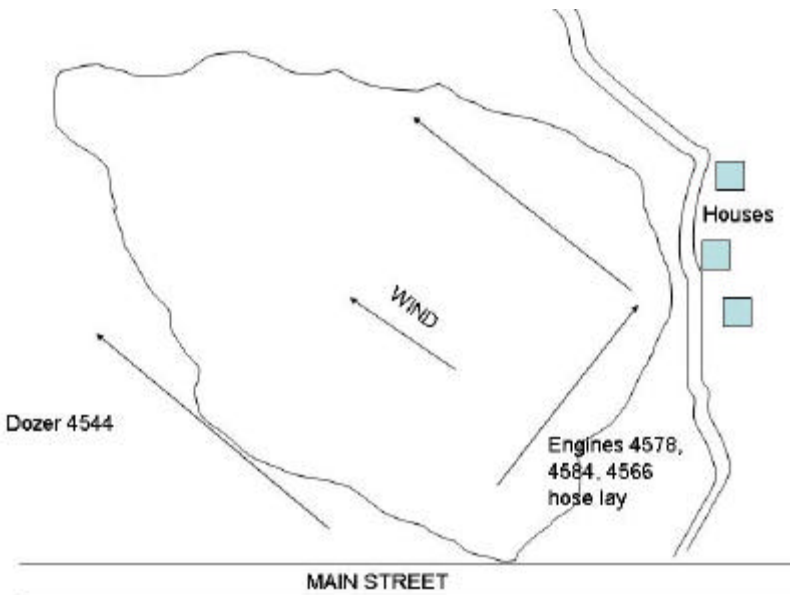
	DROP POINT (FOLLOWED BY A NAME, NUMBER, OR LETTER)
	HOT SPOT
	HELISPOT
	POINT OF ORIGIN
	SPOT FIRE AND DIRECT
	INCIDENT COMMAND POST
	CAMP
	INCIDENT BASE
	HELIBASE
	WATER SOURCE
	STAGING AREA (Identified by name)
	COMPLETED FIRE BREAK
	PLANNED FIRE BREAK
	COMPLETED DOZER LINE
	PROPOSED DOZER LINE
	UNCONTROLLED FIRE EDGE
	PLANNED FIRE LINE
	PLANNED SECONDARY
	COMPLETED FIRE LINE
	PREDICTED FIRE SPREAD (with date and time)
	DIVISION BREAKS (followed by letter)
	BRANCH BREAKS (followed by number)

Incident Maps

Incident maps can vary from a perimeter of the fire drawn on the dust on the hood of a vehicle to fully geo-rectified computer drawn maps. For the purpose of an initial attack planning strategy, a simple map on an ICS 201 showing basic information is widely used. These maps can be as simple or complex as time allows. Some of the basic information that needs to be on these maps is:

1. Current incident perimeter. This doesn't have to be exact, just a good representation of what the incident looks like.
2. Roads and other obvious land marks (so personnel can orient themselves to the incident). A north arrow is helpful for orientation of the map.
3. Locations of resources assigned to the incident.
4. Any division breaks you have identified. Use the appropriate ICS [map symbol](#).
5. Basic tactics. For example, on the right flank write in "HOSELAY" on the left flank write in "DOZER" etc.
6. Hazards or exposures. Put a square where there are houses, and write in addresses if known. Identify mine shafts, canals, etc. as potential hazards.

An example of a simple map is shown below:



On a major incident, with a GIS section filled, you will find some basic maps created. They are:

- **Briefing and Planning Maps** – Which include such things as current fire perimeter, constructed and proposed fire lines, Branch and Division Breaks, Drop Points and Staging Areas, Assignments Etc...
- **Travel Maps** – showing routes of travel around the incident
- **Fire history or progress maps.**

**NATIONAL FIRE DANGER
RATING SYSTEM (NFDRS)**
(October 2002)

7020.4

Fire Danger Rating is a numeric scaling of the potential over a large area for fires to ignite, spread and require fire suppression action. It is derived by applying local observations of current or predicted conditions of fuel, weather, topographic and risk factors to a set of complex science-based equations. The outputs of the Fire Danger Rating system are numeric measures of fire business potential that provide tools to assist fire fighters and fire managers in making the best safety and fire suppression decisions.

NFDRS OUTPUTS
(October 2002)

7020.4.1

1. **1000 Hr Fuel Moisture Content** – This value represents the modeled moisture content in the dead fuels in the 3 to 8 inch diameter class and the layer of forest floor about 4 inches below the surface. This output is a good indicator of season trends. Lower values of 1000 Hr fuels indicate more complete combustion of heavy fuels.
2. **Ignition Component** – The Ignition Component is a rating of the probability that a firebrand will cause a fire requiring suppression action. Scale ranges from 1 to 100. An IC of 100 means that every firebrand will cause an “actionable” fire if it contacts a receptive fuel.
3. **Spread Component** – The Spread Component is a rating of the forward rate of spread of a head fire. The SC is numerically equal to the “theoretical ideal” rate of spread expressed in feet-per-minute. SC is expressed on an open-ended scale, thus has no upper limit. SC does not take into account spotting.

4. **Energy Release Component** – The Energy Release Component is a number related to the available energy (BTU) per unit area (square foot) within the flaming front at the head of the fire. ERC uses relative fuel moistures of both live and dead classes. The scale is open-ended and is relative. As both live and dead fuels dry out, ERC values get higher thus providing a good reflection of drought.
5. **Burning Index** – The Burning Index is a number related to the contribution of fire behavior to the effort of containing a fire. BI is expressed as numeric value closely related to the flame length in feet multiplied by 10. The scale is open ended. If a fire occurs in the worst fuel, weather and topography conditions of the rating area, these numbers indicate its expected fireline intensities and flame length.

FIRE DANGER CLASSES (October 2002)

7020.4.2

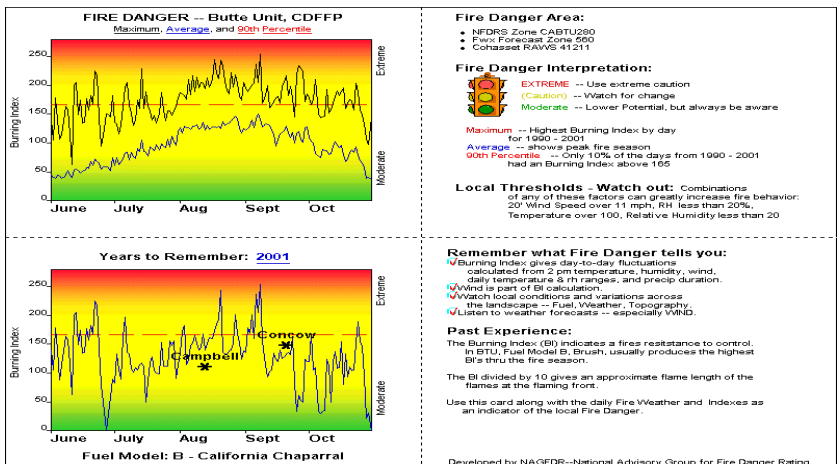
In 1974 the Wildland Fire Agencies established a standard adjective description for 5 levels of fire danger for use in public information releases and fire prevention signing.

Fire Danger Class and Color Code	Description
Low (Green)	Fires do not ignite readily from small firebrands. Fires in open grasslands may burn freely a few hours after rain, but other fuels spread slowly. There is little danger of spotting.
Moderate (Blue)	Fires can start from most accidental causes. Fires in open grasslands will burn briskly and spread rapidly on windy days. Timber fires spread slowly. Fires are not likely to become serious and control is relatively easy.
High (Yellow)	All fine fuels ignite readily and fires start easily from most causes. Fires spread rapidly and short-distance spotting is common. Fire may become serious and there control difficult unless they are hit hard and fast while small.
Very High (Orange)	Fires start easily from all causes and, immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high intensity with long-distance spotting and fire whirls when they burn in heavier fuels.
Extreme (Red)	Fires start quickly, spread furiously and burn intensely. Direct attack is rarely possible and may be dangerous except immediately after ignition. Under these conditions the only effective and safe control action is on the flanks until the weather changes or the fuel supply lessens.

FIRE DANGER POCKET CARDS (October 2002)

7020.4.3

Pocket cards are a simple concept that were developed to provide for increased Fire Fighter safety by providing information on historical weather trends and indices for a specific area. This card provides a wide variety of graphical information on historical weather trends, years of particular interest, and indicates fires of historical significance. The cards are easily created using historical weather data from any NFDRS station. They can be easily reproduced and distributed. These are particularly valuable for Fire Fighters that are in an area where they may not be familiar with local weather trends, fuel conditions or unusual conditions. When used in conjunction with local fire weather forecasts, an easy comparison can be made between actual conditions and historical trends. Fires that were of historical significance in the recent past can be added to compare those conditions, as they existed comparison.



(see next section)

(see HB Table of Contents)

(see Forms or Forms Samples)